# Introduction of RAVEN


Internal meeting on future instrument projects at Subaru

2010/4/26 @ Hilo

Shin Oya（Subaru Telescope/NAOJ)

# Outline

- RAVEN project
  - project outline
  - Multi-Object Adaptive Optics (MOAO)
- Subaru Telescope and RAVEN
  - carry-in instrument (PI instrument)
  - NsIR platform (2013～2015)
  - support for the design & science (2010～)

    face-to-face meeting on September 24&25, 2009

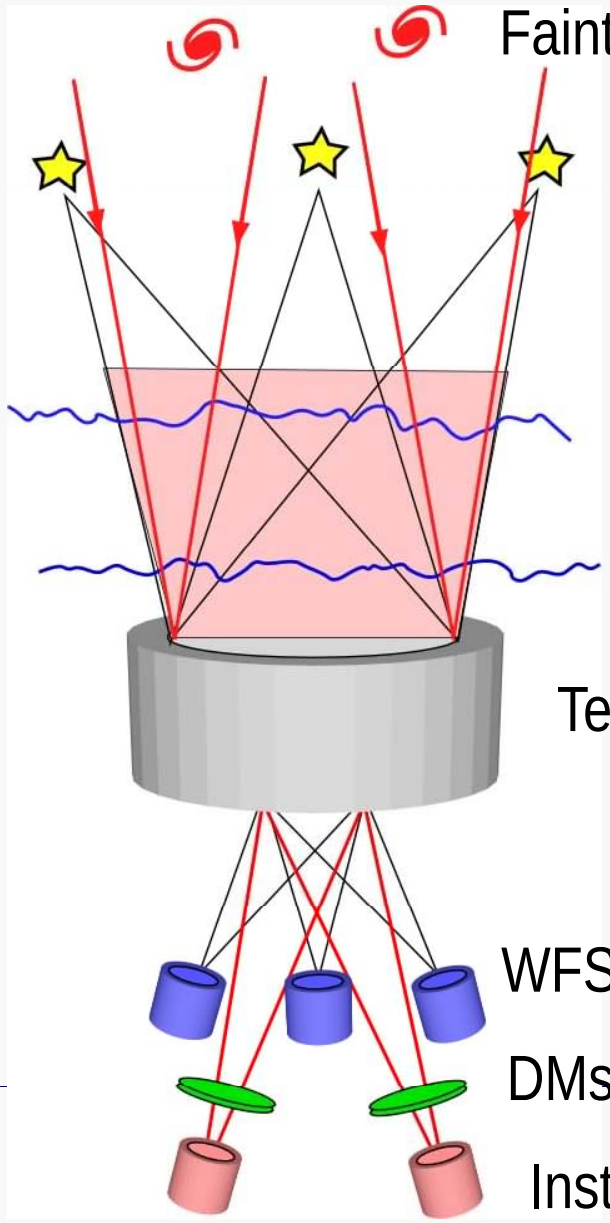
    kick-off meeting on March 16&17, 2010
- Schedule

# RAVEN Project

- MOAO demonstrator
  - laboratory experiment
  - on-sky scientific verification
- Led by Canadian Group
  - University of Victoria (UVic)
  - Hezberg Institute for Astronomy (HIA)
- Already Funded
  - 6M CAD by BCKDF/CFI Leading Edge Fund
  - In kind contribution from HIA & Subaru (> 400K CAD)

- 2013～2015 Hilo/Summit
- The first 8m-class MOAO system

# MOAO



Faint Objects

Guide Stars

Telescope

WFSs

DMs

Instruments

FOV:
-patrol: ~arcmin
-unit: ~arcsec

Tomographic wavefront reconstruction

Key Technologies

Open-loop control

TMT
THIRTY METER TELESCOPE

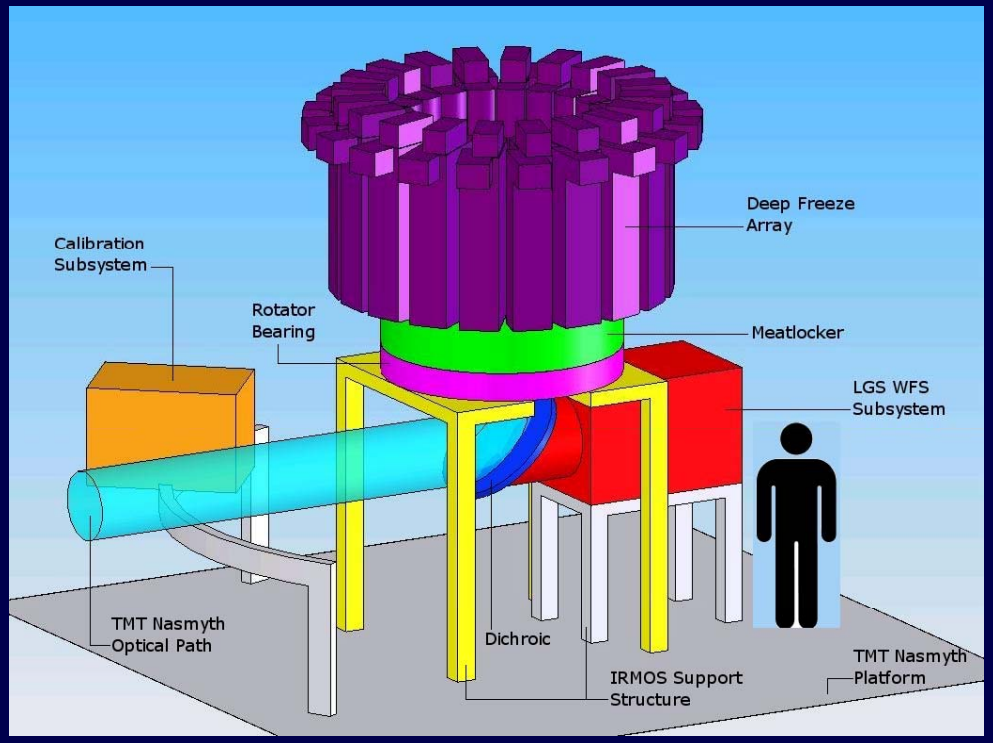
# TMT First Decade Instrument Suite

| Instrument | λ (μm) | Field of view/ Slit length | Spectral resolution | Science Cases |
|---|---|---|---|---|
| InfraRed Imager and Spectrometer (IRIS) | 0.8 – 2.5<br>0.6 – 5 (goal) | <3″ IFU<br>>15″imaging | > 3500<br>5-100 (imaging) | • Assembly of galaxies at high z<br>• Black holes/AGNs/Galactic Center<br>• Resolved stellar populations in crowded fields |
| Wide-field Optical spectrometer and imager (WFOS) | 0.31 – 1.0 | >40 arcmin$^2$<br>>100 arcmin$^2$ (goal)<br>Slit length>500″ | 1000-5000@0.75″ slit<br>>7500 @0.75″ (goal) | • IGM structure and composition at 2 < z < 6<br>• Stellar populations, chemistry and energetics of z > 1.5 galaxies |
| InfraRed Multislit Spectrometer (IRMS) | 0.95 – 2.45 | 2 arcmin field, up to 120″ total slit length with 46 deployable slits | R=4660 @ 0.16 arcsec slit | • Early Light<br>• Epoch of peak galaxy building<br>• JWST follow-ups |
| Deployable, multi-IFU, near-IR spectrometer (IRMOS) | 0.8 – 2.5 | 3″ IFUs over >5′ diameter field | 2000-10000 | • Early Light<br>• Epoch of peak galaxy building<br>• JWST follow-ups |
| Mid-IR AO-fed Echelle spectrometer (MIRES) | 8 – 18<br>4.5 – 28 (goal) | 3″ slit length<br>10″ imaging | 5000-100000 | • Origin of stellar masses<br>• Accretion and outflows around protostars<br>• Evolution of gas in protoplanetary disks |
| Planet Formation Instrument (PFI) | 1 – 2.5<br>1 – 5 (goal) | 1″ outer working angle, 0″.05 inner working angle | R≤100 | • $10^8$ contrast ratio ($10^9$ goal)<br>• Direct detection and spectroscopic characterization of exoplanets |
| Near-IR AO-fed echelle spectrometer (NIRES) | 1 - 5 | 2″ slit length | 20000-100000 | • IGM at z > 7, gamma-ray bursts<br>• Local Group abundances<br>• Abundances, chemistry and kinematics of stars and planet-forming disks<br>• Doppler detection of terrestrial planets around low-mass stars |
| High-Resolution Optical Spectrometer (HROS) | 0.31 – 1.1 | 5″ slit length | 50000 | • Doppler searches for exoplanets<br>• Stellar abundance studies in Local Group<br>• ISM abundance/kinematics<br>• IGM characteristics to z~6 |
| "Wide"-field AO imager (WIRC) | 0.8 – 5.0 | 30″ imaging field | 5-100 | • Precision astrometry (e.g., Galactic Center)<br>• Resolved stellar populations out to 10 Mpc |

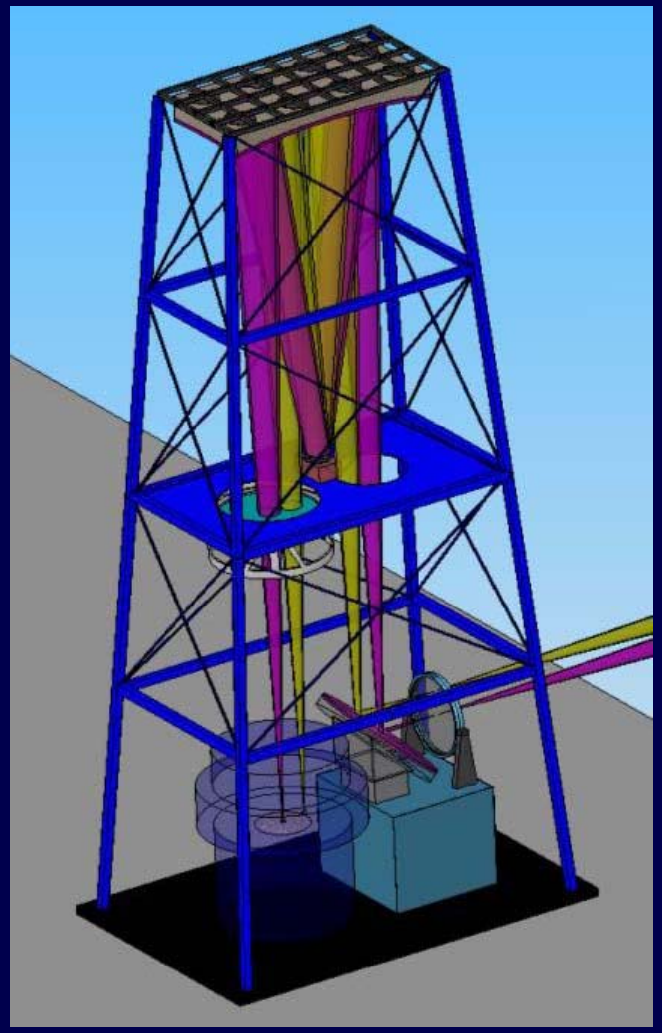
2nd gen

# MOAO for TMT

## UF / HIA




## Caltech



Feasibility study in 2006

- opto-mechanical design
- performance evaluation
- system engineering

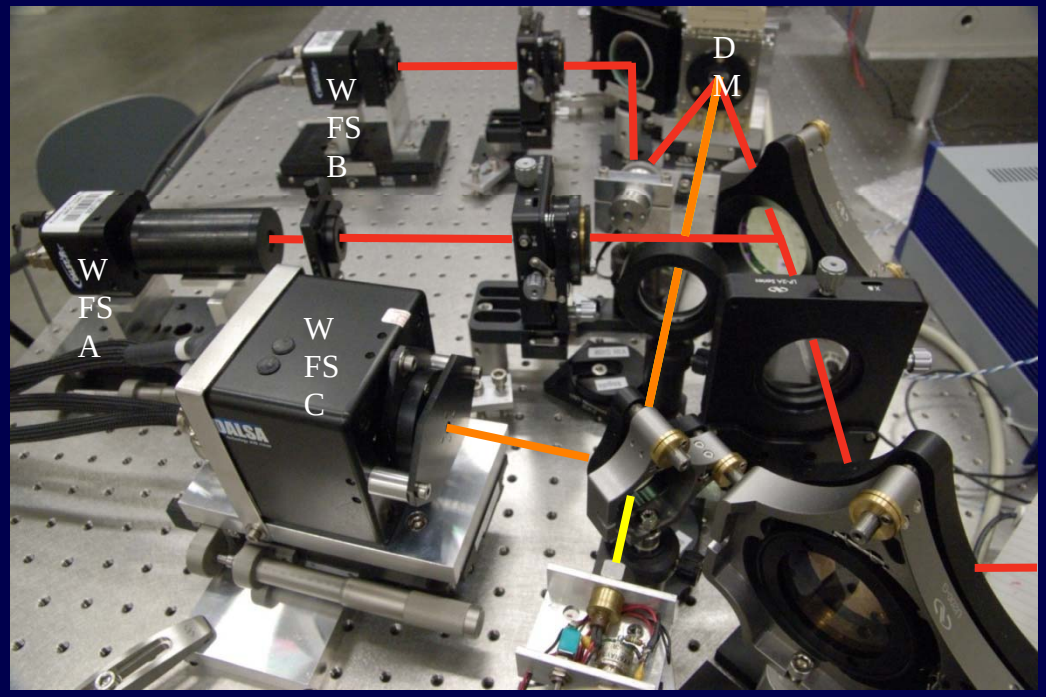
# Already done in Canada

Succeeded in on-sky open-loop correction

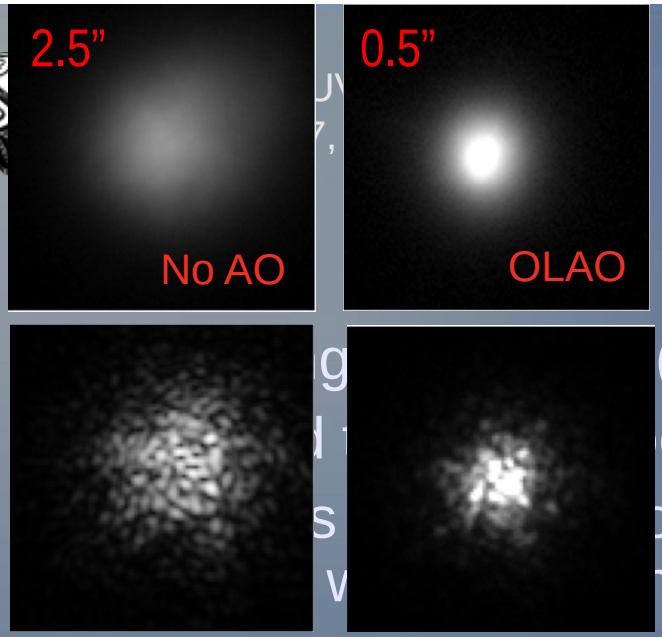
VOLT: Victoria Open-Loop Testbed

Andersen et al.,Proc.SPIE,7015,70150H

– single channel
– on-axis
– on-sky (May, ’08)
– 1.2m telescope
– Arcturus (R=0.3)



# VOLT on-sky results




(80ms) on OL WFS A to center starlight

cus to achieve proper platescale

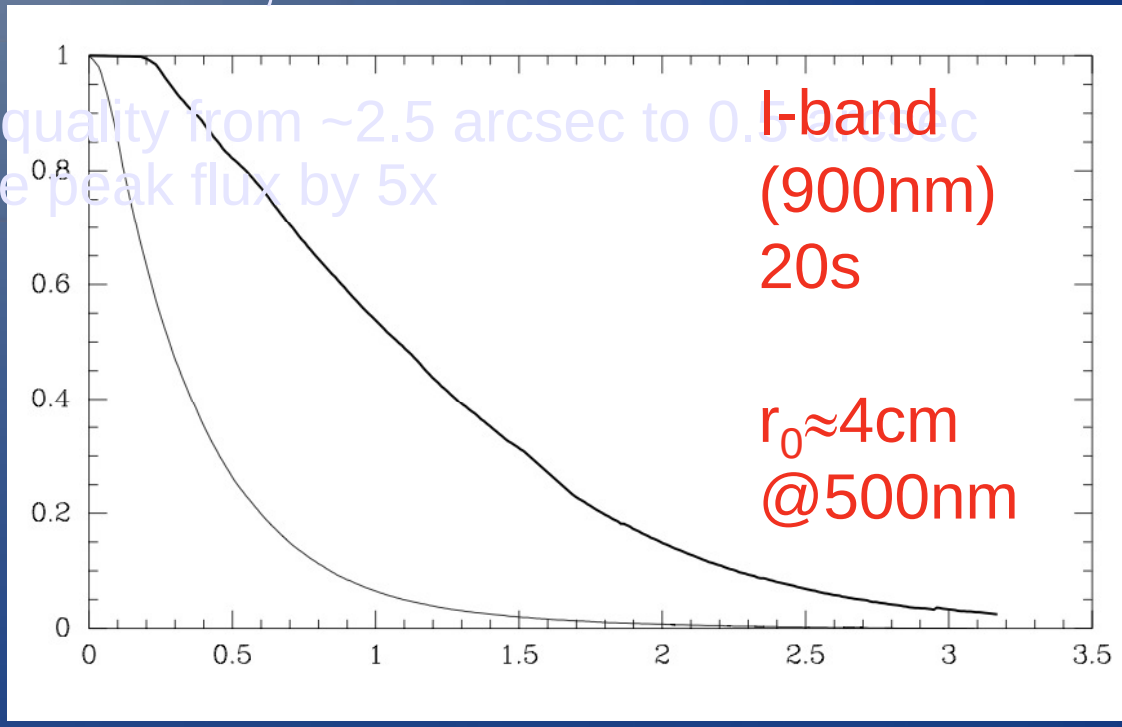
short exp.

on a very bright star, our threshold on the

simulation?

he readnoise

- As predicted by CAOS simulations, we did not achieve the diffraction limit
- We improved the image quality from ~2.5 arcsec to 0.5 arcsec FWHM and increased the peak flux by 5x



# To be done at Subaru

The first 8m-class demonstration of MOAO

Challenges at Subaru:

- on-sky tomographic wavefront reconstruction using multiple-NGSs
- calibration method of the system
- scientific verification

  for example:

  - metal-poor star search in the Galactic bulge
  - Herbig-Haro objects, silhouette disk

limiting GS mag : 10 -12 mag

# Raven

- Raven is a down-scale MOAO prototype, precursor of MOAO on ELTs
  - 3 WFSs patrolling a 2.0 arcmin field-of-view
  - 2 deployable DMs plus a fixed woofer
  - 2 “truth” WFSs
  - 2 science paths feeding IRCS
  - Slit spectrograph IRCS
  - FPGA based RTC
- 3-4 years development phase
- On sky test in the last year

# Configuration w/ Subaru

- Subaru will provide:
  - Telescope (NsIR)
  - IRCS
  - AO188 (TBD)
  - technical support (man power)

- Relation between AO188 and RAVEN
  1. Telescope direct w/o AO188
  2. AO188 w/ BIM188 woofer correction
  3. AO188 w/o BIM188 woofer correction

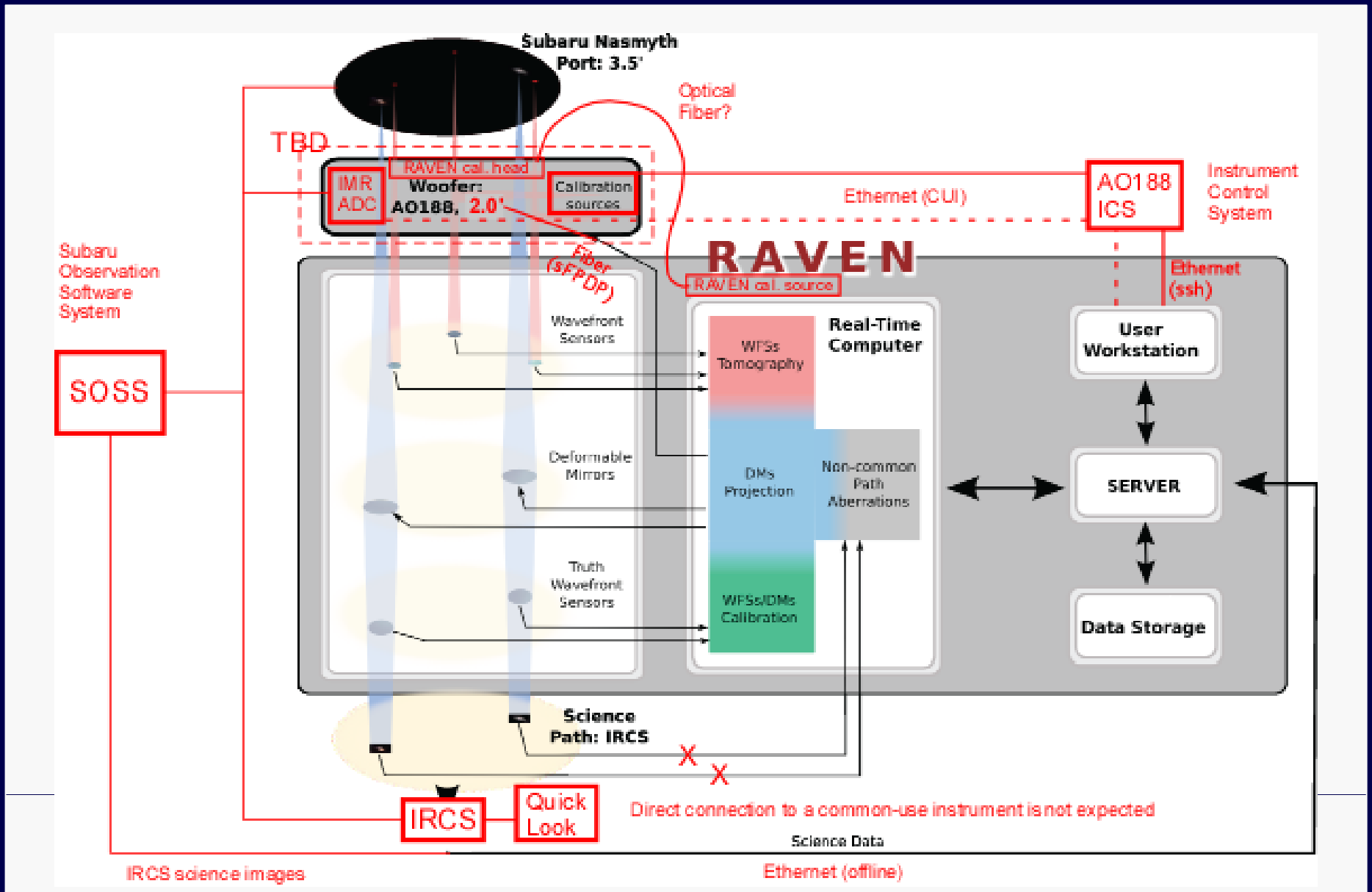
meeting
5/1-5/3
@Hawaii

No new focus will be added (use existing NsIR or NsIR+AO188 focus)

# Computer / SOSS

- Computer
  - all PCs/electronics will be placed at NsIR (baseline)
  - computer room space needed? (TBD)
  - summit network (E-LAN)
- SOSS
  - during experiment observation, we do not prepare inerface for RAVEN
  - SOSS will be used for Telescope & IRCS (AO188)
  - If the project is extended to accept proposals, RAVEN will prepare SOSS interface (TBD)

# System Diagram



# Time Line

**Preliminary Timeline:**

| RAVEN Timeline | | | DATE: | Jan-10 | Jul-10 | Jan-11 | Jul-11 | Jan-12 | Jul-12 | Jan-13 | Jul-13 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Task** | **Subtask** | **# People Assigned** | **Est. Time (Months)** | | | | | | | | |
| **System Modeling** | | **TBD** | | | | | | | | | |
| | Phase 1 | | 6.0 | | | | | | | | |
| | Phase 2 | | 7.0 | | | | | | | | |
| | Phase 3 | | 15.0 | | | | | | | | |
| **Opto-Mechanical Design** | | | | | | | | | | | |
| | Conceptual Optical Design | | 6.0 | | | | | | | | |
| | Preliminary OMD | | 8.0 | | | | | | | | |
| | Final OMD | | 6.0 | | | | | | | | |
| **Software and Computing** | | | | | | | | | | | |
| | Preliminary Software Design | | 12.0 | | | | | | | | |
| | RTC Development & Integration | | 8.0 | | | | | | | | |
| **Procurement** | | | | | | | | | | | |
| | Place component orders | | 12.0 | | | | | | | | |
| **Integration** | | | | | | | | | | | |
| | Integrate system at UVic AO Lab | | 10.0 | | | | | | | | |
| **Testing** | | | | | | | | | | | |
| | UVic AO Lab Testing | | **8.0** | | | | | | | | |
| | Hilo Testing | | 4.0 | | | | | | | | |
| | Subaru Testing | | 6.0 | | | | | | | | |
| **Total Months Work** | | | | | | | | | | | |

# What's coming next

- RAVEN team visits Subaru (Hilo/summit)
  - May 1st - 3rd
  - discussion on the configuration at NsIR
- Carry-in instrument proposal submission
  - August?
- Conceptual Design Review
  - September?

# Summary

- Introduction of RAVEN project
  - on-sky MOAO demonstrator
  - Canadian fund and group
- Subaru Telescope and RAVEN
  - carry-in instrument installed on NsIR platform
  - Subaru will support the project as a partner
  - tomography, calibration, scientific verification, etc
- Schedule
  - 3 ～ 4 year project (2013～ Hilo/Summit)
  - RAVEN team visit (5/1 – 5/3)

# Appendix

# Raven: Funds & Partners

- $6 Million CAD BCKDF/CFI Leading Edge Fund
- In kind contribution from HIA & Subaru telescope
- Collaborators
  - TMT
  - DRAO Penticton
  - UBC
  - University of Florida
  - Durham University
  - Lyrtech
  - INO

# Infrared Multi-Object Spectrograph (IRMOS)

**Deployable IFU spectrometer fed by Multiple Object AO**

- NIR: 0.8-2.5μm
- FoV: IFU heads deployable over 5 arcmin field
- Image quality: diffraction-limited images, tip-tilt ≤0.015 arcsec rms
- Spatial sampling
  - 0.05x0.05 arcsec pixels, each IFU head 2.0 arcsec FOV, ≥ 10 IFU units
- Spectral resolution
  - R=2000-10000 over entire J, H, K bands, one band at a time
  - R=2-50 for imaging mode

Two IRMOS concepts were competitively studied as part of the TMT instrument feasibility study phase in 2005 - 2006. One concept ("TiPi") originated from Caltech (PI: R. Ellis) , and the other concept ("UF") was proposed by a University of Florida team (PI: S. Eikenberry).

# Proposed MOAO for TMT

| | Caltech | UF/HIA |
|---|---|---|
| FOV(deployable) | 5 arcmin | 5 arcmin |
| FOV(unit) | 1.5 arcsec | 2.2 arcsec |
| # of unit | 16 | 20 |
| wavelength | 0.8 ~ 2.5μm | 0.8 ~ 2.5μm |
| spectral res. | R=2,000 ~ 10,000 | R=1,000 ~ 20,000 |
| speacial res. | 12.5 ~ 50mas | 16 ~ 50mas |

# VOLT on-sky results

- Used long exposures (80ms) on OL WFS A to center starlight
- Changed telescope focus to achieve proper platescale
- For ~1ms exposures on a very bright star, our threshold on the OL WFS was above the readnoise
- As predicted by CAOS simulations, we did not achieve the diffraction limit
- We improved the image quality from ~2.5 arcsec to 0.5 arcsec FWHM and increased the peak flux by 5x

# Subaru Nasmyth IR